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# Kongeriget Danmark

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The attached photocopy is a true copy of the following document:

- The specification, claims, abstract and drawing as filed with the application on the filing date indicated above.



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**Modtaget**

**Reactor for carrying out non-adiabatic reactions**

The present invention relates to a reactor for carrying out non-adiabatic reactions in general. More particularly, the invention provides a reaction system for use in the conversion of a feedstock by endothermic or exothermic reactions especially in small-scale industrial applications and for installation in vehicles.

Endothermic or exothermic reactions require constant supply or removal of heat for maintaining reasonable reaction rates. Heat is in industrial reactors for carrying out those reactions usually transferred by convection or radiation from a heat conducting medium. During endothermic reactions, necessary heat is usually supplied indirectly by hot flue gas obtained by combustion of fuel. Cooling of exothermic reactions is typically performed indirectly by heat exchange with a hot fluid or directly through addition of cold quenches gases.

In small sized chemical plants and in mobile use of endothermic reactors, combustion of fuel is in general a disadvantage due to environmental and safety regulations requiring emission purification and expensive measures to prevent danger of fire.

The general object of this invention is thus to provide a reactor or reaction system for use in the above mentioned small size applications being carried out in a compact reactor. Heat is supplied or removed by means of indirect heat conduction with a heat-conducting medium or means such as oil, steam, by electrical heating means and cooling liquids.

The above heat conducting media and electrical heaters are conventionally employed in heating of reactors in laboratory or bench-scale size.

5 It is further known to heat different catalyst structures electrically. Those methods are typically used in catalytic purification of automobile exhaust and for start-up procedures in catalytic converters (US Patent Nos. 5,070,694; 5,456,890 and 6,109,018).

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The reactor of this invention consists in its broadest aspect of a metallic ingot comprising at least one reaction passage extending through the ingot and being adapted to hold a catalyst for non-adiabatic conversion of a feed-

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stock; inlet passages for introduction of the feedstock into the reaction passage and outlet passages for withdrawing reacted feedstock, the inlet and outlet passages being provided within the ingot; and

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means for heat or cooling the ingot and the reaction passage to maintain the catalytic non-adiabatic conversion of the feedstock.

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Materials and dimension of the reactor and different passages will be selected in accordance with the intended application of the reactor. Convenient metallic materials are those that have proper heat conducting properties and are mechanical and chemical stable at operation conditions.

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The reactor according to the invention is in particular useful in small sized applications as introductorily mentioned. Those applications include in particular prepara-

tion of hydrogen from methanol containing feed gas for use in fuel applications in vehicles or on board of ships.

5 A convenient method to construct the above reactor will be drilling one or more reaction passage through a metallic ingot or block. Typically, the reactor contains a number of reaction passages, wherein the passages are drilled in series of parallel rows through the ingot and supplied with the feedstock through drilled passages extending in a substantially perpendicular direction to the reaction passages and thereby being connected with the reaction passages in parallel manner. Preferably, in a multi reaction passage reactor of the above type each row of reaction passages will be connected with an inlet passage at inlet side of the reactor. In similar manner, reacted feedstock is withdrawn from the reactor through outlet passages parallel connecting the reaction passages at outlet end of the reactor and being drilled within the ingot in substantially perpendicular direction to the reaction passages.

20 The entire ingot is heated or cooled by a heat conducting medium flowing in passages being embedded in the ingot machined within the ingot structure or applied at the structure surface.

25 When employing the inventive reactor in praxis, catalyst is loaded into the reaction passages either in form of particles or as coating, film or paint on inner wall of the passages. The reaction passages are fluid tight closed at top and bottom end by conventional means prior to operation of the reactor.

Construction and operation of the inventive reactor will be apparent in more detail from the following description by reference to the drawings in which the sole Figure shows a specific embodiment of the invention employed in endothermic conversion of a hydrocarbon feedstock.

A reactor 2 according to a specific embodiment of the invention consists of metallic blocks 4 and 6. Block 4 and 6 are provided with a series of parallel reaction channels 8 and 10 drilled through the blocks. Each series of channels is connected to main feed inlets 12 and 14 connecting each row of channels 8 and 10 in parallel.

Reacted feed is withdrawn from channels 8 and 10 through main outlets 16 and 18.

Each of blocks 4 and 6 is further provided with a number of electrical heating strips 26 and 28 within outer surfaces of block 4 and strips 30 and 32 within outer surface of block 6 or in groves (not shown) in the surface. The blocks are collected within a common shell 34 provided with shelves 36 to support insulating material (not shown) at the outer surface of shell 34.

When employing the above described reactor in the preparation of hydrogen by catalytic cracking of alcohol, channels series 8 and 10 are loaded with conventional cracking catalyst, e.g. in form particles.

Prior to loading the channels and operating the reactor, the open ends of the channels are sealed with plugs being welded or screwed into the open ends.

Alcohol containing feed gas is introduced into the reactor via main inlets 12 and 14 and distributed to channel rows 8 and 1.

- 5      Within the channels, the feed gas is converted to hydrogen rich process gas by known alcohol cracking reactions proceeding on conventional cracking catalyst (not shown). The produced process gas is finally withdrawn from the channels via the outlet passages as described above.

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Necessary heat for the cracking reactions is supplied to the catalyst by heating the entire reactor 2 with heat being generated by the electrical heating strips.

**CLAIMS**

1. Reactor for carrying out non-adiabatic catalytic reactions consisting of a metallic ingot and comprising at least one reaction passage extending through the ingot and being adapted to hold a catalyst for non-adiabatic conversion of a feedstock;

inlet passages for introduction of the feedstock into the reaction passage and outlet passages for withdrawing reacted feedstock, the inlet and outlet passages being provided within the ingot; and

heating or cooling means for maintaining the catalytic reactions within the reaction passage.

2. The reactor of claim 1, wherein a number of the reaction passages is arranged in parallel rows within the ingot.

3. The reactor of claim 1, wherein the inlet and outlet passages are provided within the ingot substantially perpendicular to the reaction passages and connect the reaction passages in parallel manner.

4. The reactor of claim 1, wherein the heating or cooling means are arranged within and/or at surface of the ingot.

5. The reactor of claim 1, wherein the heating or cooling means is provided in a substantially perpendicular direction with the reaction passages.



6. The reactor of claim 1, wherein the heating means is in form of electrical heater.

5 7. A reactor containing a number of the metallic ingots according to claim 1.

8. The reactor of claim 7, wherein the number of the metallic ingots is arranged within a common shell.

10 9. The reactor of claim 8, wherein the common shell is heat insulated.

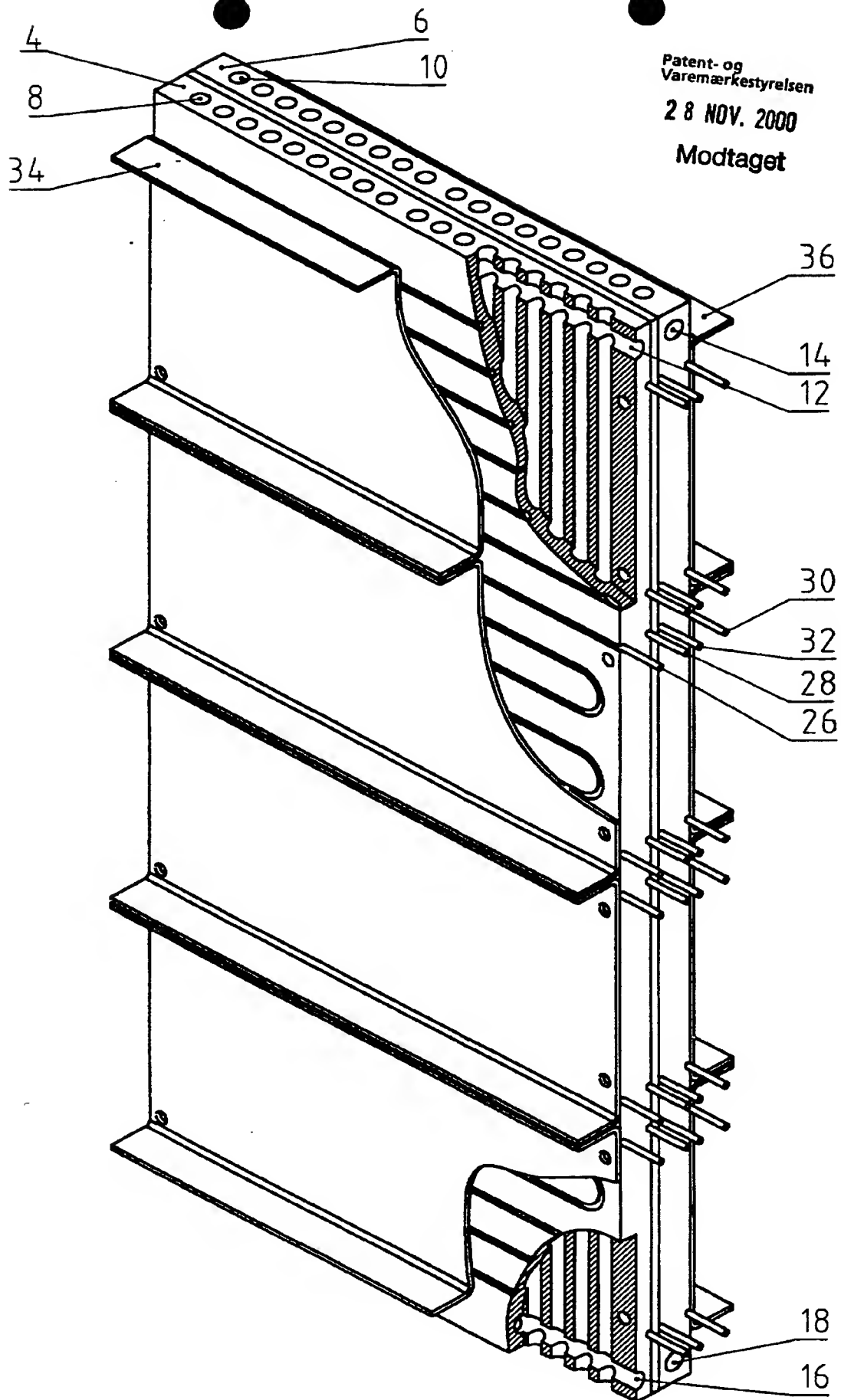
15 10. The reactor according to any one of the preceding claims, wherein the reaction passages and the outlet and inlet passages are in form of drilled channels.

**ABSTRACT**

Reactor for carrying out endothermic catalytic reactions consisting of a metallic ingot and comprising at least one  
5 tubular reaction passage extending through the ingot and being adapted to hold a catalyst for endothermic conversion of a feedstock;

inlet passages for introduction of the feedstock into the reaction passage and outlet passages for withdrawing re-  
10 acted feedstock, the inlet and outlet passages being provided within the ingot; and

electrical heating means for heating the ingot and the reaction passage to supply heat for the catalytic endothermic conversion of the feedstock.



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